

Nonmetal Batteries

Introduction

Since the industrial revolution, humans have been burning fossil fuels such as coal, oil, and natural gas to produce the energy we use to heat our homes, turn on our lights, and power our machines. However, we have come to understand that burning fossil fuels generates carbon dioxide that leads to climate change. To help address this, there has been rapid development of solar and wind energy technologies, which have become increasingly available and inexpensive. Solar and wind power have a big problem, though: They are intermittent. An intermittent energy source is one that is available only at certain, uncontrollable times. In other words, we can't get any energy from wind on a day when the wind isn't blowing, and we can't get energy from the sun when it's nighttime.

One solution to this problem with solar and wind energy is to store the energy source when we have it, and then use the stored energy at times when it's not available. For example, a lot of energy can be produced on a very sunny or windy day, sometimes more than what is needed. If we could store the extra energy, then we could use it at other times, like when it's dark or not-so windy. How do we store energy? Batteries!

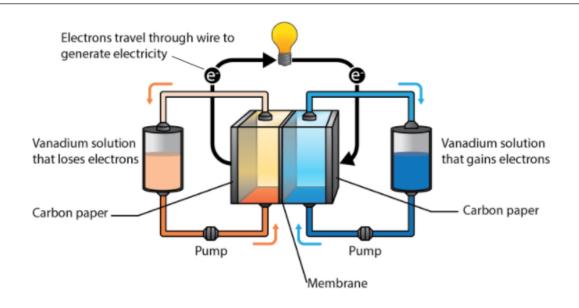


Figure 1. Diagram of a Redox Flow Battery. In a redox flow battery, two substances are pumped across different sides of a porous membrane. One substance loses an electron while the other gains an electron. The electrons travel through a wire, generating electricity. In many redox flow batteries, different vanadium compounds are used on each side of the membrane. Vanadium can both lose and gain electrons easily, because it can be stable when it has 0, 1, 2, or 3 valence electrons.



Wind and solar energy companies have started to use a type of battery known as a **redox flow battery** to store energy. **Figure 1** shows a simplified redox flow battery. Redox flow batteries store energy in chemical compounds dissolved in water (the orange and blue in the diagram). These compounds are pumped from separate storage tanks to a chamber where they are separated by a membrane. Each side of the chamber has a wall made of carbon paper. In the center chamber, one of the compounds (the orange one in the diagram) loses an electron which travels through the carbon paper to a metal wire and all the way to the other side of the battery where it is gained by the other compound (blue in the diagram). This flow of electrons from one compound to the other creates electricity. The membrane separating the two substances allows positive ions to travel between the sides. Without the membrane, charge would build up and the flow of electrons would stop.

Historically, redox flow batteries have used the element vanadium to store their energy because like all metals, vanadium transfers electrons easily. Vanadium can be stable when it has 0, 1, 2, or 3 valence electrons. This is very unusual and means that vanadium has two lower-energy and two higher-energy states, which means that vanadium can be used on both the positive and the negative side of the same battery. Woo woo! Go vanadium!

There is a problem with using vanadium, though—there isn't very much vanadium in Earth's crust which means it is expensive to use in large scale batteries. In 2014, scientists at Harvard University proposed replacing the vanadium with something else. In this lesson, you will learn about their idea and how it might help us solve our clean-energy storage problem.

Nhat To Do

Answer the analysis questions below, reading the Bite when instructed.

- Analysis Questions

1. In your own words, define "intermittent." Explain why an intermittent energy source is a problem.

- **2.** Look at the redox flow battery in **Figure 1**.
 - **a.** What is the purpose of the carbon paper? Why is that important for the functioning of the battery?





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b.	What i	is the purpose of the membrane? Why is that important for the functioning of the	
	Dattery	y :	
c.	Why d	lo you need two different vanadium solutions in a redox flow battery?	
	j		
STOP & read Science Site:			
	Building a Better Battery		
What are anthraquinones? Where do they occur naturally?			
Vanadium and AQDS can both be used in batteries. They each have advantages and			
disadvantages. Complete each of the following sentences by writing either "vanadium" or "AQDS" in each blank. are the major advantages and disadvantages of each?			
	a.	A major disadvantage of is that it is rare and expensive.	
	b.	A major disadvantage is that it breaks down into other molecules.	
	c.	Batteries made with usually last about a year or two.	

e. Scientists can modify organic compounds like _____ to make them more

d. Batteries made with _____ last only for a week or so.

useful in batteries.

3.

4.



The electrons transferred to AQDS when the battery is charged come from bromide. Write a balanced half-reaction equation to represent the transformation bromide (Br ⁻) undergoes during the charging of a battery containing anthraquinones.
Is bromide oxidized or reduced during the battery charging process? Justify your choice.
What is capacity retention and why is it important?
What are the next steps for researchers as they attempt to make a redox flow battery for wide application?
Connect to the Big Question: How do scientists know if a redox flow battery is working? What evidence do they look for in the lab to confirm this?